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Enhancing Critical Thinking Skills of Junior High School Students through Discovery-Based Multiple Representations Learning Model

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This study aimed to measure the effectiveness of the Discovery-based Multiple Representation (DMR) learning model that use to improve student critical thinking skills (CTS) of students on environmental change material. This study used the pre-experiment method, with a one-group pretest-posttest design. The populace of this study was students in MTs 2 Sleman. The sample was selected by a random sampling technique amounting to 60 people. The instrument used to collect data on critical thinking capability was an essay test to measure the effectiveness of the DMR learning model in increasing students' CTS. The data analysis technique used paired sample t-test with (p= .05) to test the effectiveness of the DMR learning model. The results showed that the DMR learning model increased student CTS significantly in natural science learning. The normalized gain value of 0.25 indicates the enhancement of student CTS at the middle category. Thus, the DMR learning model is useful as an alternative to improve students' CTS on environmental change topics.

Keywords: critical thinking skills, discovery, learning, multiple representations, natural science learning, thinking skills

INTRODUCTION

The 21st-century educational paradigm has implications for changes in the learning system and an emphasis on increasing the ability to think (Ledward & Hirata, 2011). These need to be done so that students always develop and can compete in the global

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world. Students have to formulate problems, think critically, creatively, and collaborate in solving these problems (Farisi, 2016; Greenstein, 2012; Trilling & Fadel, 2009). Based on this statement, learning natural science is also necessary to facilitate student's development of their thinking levels, because thinking skills are a basics concept for learning and living life.

Critical thinking skills (CTS) is one of the higher-order thinking skills needed in the 21st century (Rotherham & Willingham, 2010; Saleh, 2019). Students who have high CTS are more skilled in decomposing structures into components, are more active and creative in solving problems, and have a great curiosity about the phenomenon (Chang et al., 2015). CTS affects the conceptual system formation of students. Learning with CTS is very helpful, for example, helping students to establish their understanding (Maknun, 2020); activated long-lasting memory (Adzim, 2020); and practicing problem-solving skills (Hung et al., 2008). Therefore, learning CTS has to be empowered for students in learning natural science.

The selection of science subject matter refers to the nature of science itself which consists of scientific processes, scientific products, scientific attitudes and applications (Abruscato, 2003; Chiappetta & Koballa, 2010), it is hoped that these four components are in the science learning process, so that students can experience the learning process holistically and can understand natural phenomena through investigation with the scientific method. Science is implemented by facilitating active student learning to build it themselves through discovery (Rustaman et al., 2011), as explained by Dimyati (2006) states that the main purpose of learning is to teach students to be able to acquire and process knowledge, skills, and attitudes. Therefore, science learning should be carried out by applying integrated learning because in essence it is to provide opportunities for students to actively explore and discover concepts and principles as a whole and authentic, so that students get direct experience in learning which has an impact on increasing the power to accept, store, and produce the knowledge they learn.

However, the problem is the natural science learning is still oriented towards conceptual abilities. It does not pay attention to other aspects such as procedural skills and high-level reasoning by the scientific method process. Silberman (1996) also confirmed that learning in schools prioritizes conceptual, while the scientific method process, the basic of CTS, is less trained. Even though scientific method-based, it can foster CTS, students have better literacy and become accustomed to solving problems faced in everyday life, so it could be more successful for student learning outcomes (Roser et al., 2013).

As a result of the learning process from the scientific method, it results in a low level of critical thinking skills of students in various developing countries (Memon, 2007; Nauman, 2017). These results are reinforced by the 2018 PISA report, which states that the literacy, mathematics and science performance of SMP/MTs students in Indonesia is also still low, as can be seen from the average science of Indonesian students which is lower than the ASEAN average (OECD, 2019). The questions used by PISA consist of 6 levels (lowest level 1 and highest level 6), students in Indonesia are only able to answer at level 1 and level 2 around 40% while the average from the OECD is 78% (OECD, 2019). This shows that students' ability to answer questions that refer to critical thinking

skills is still low. Besides, the initial test results of 118 students at MTs (Islamic Junior High School) 2 Sleman, after working on the description questions, the mean CTS was 37.89 which classified as the low category, which detailed in the aspect of clarity assumption of 42.46, interpretation of 28.23, analysis of 34.906, inference of 33.60, evaluation of 39.00, reason of 41.20, and self-regulation of 45.50.

The results of a preliminary study in September 2019-February 2020 were carried out in several State MTs in Sleman district by giving questionnaires to 16 science teachers to determine the science learning process, the CTS of students who were taught using models, and methods that are usually used in class. According to the science teacher at MTs 2 Sleman, it was revealed that the teacher was not emphasizing multiple representations in the learning activities, so this had an effect on the ability to interpret and understand the science concepts they received, for example, when teaching environmental change materials. These happen by delivering stimuli at the beginning of learning that do not display information in the form of tables, pictures, or graphs with contexts that are not routine, and in question exercises students tend to be mathematically verbal by directly applying formulas and calculations. At the data collection stage, the teacher has not facilitated students to optimize new literacy skills, namely, digital literacy which improves reading, analyzing, and using information. Besides, at processing data and verification stages, the teacher has not facilitated students to present it in various representations so that the interpretation process is limited. Students sometimes may be able to interpret concepts in pictures but are unable in diagrams or graphs before solving them with mathematical equations.

Therefore, to overcome the problem of the lack of fulfillment of the indicators that are the learning objectives including the indicators of students CTS is to choose a learning model that is student-centered, able to construct knowledge, and based on scientific methods, one of which is the DMR learning model (Chusni et al., 2020). The DMR learning model has the characteristics of hands-on and minds-on syntax with a sequence of activities, namely orientation, simulation-based multiple representations, exploration, data literacy, present and verification, and conclusion. The syntax of DMR learning model is developed based on the procedures of scientific method (Carey, 2011; Hugerat & Kortam, 2014). Discovery-based learning has been proven effective in improving students' critical thinking skills (Halliru & Slade, 2017) because it encourages students to identify problems, arouse curiosity, collect data, organize knowledge, and understand the material independently (Bano et al., 2019). Thus, this study aimed to measure the effectiveness of the DMR learning model that use to improve student critical thinking skills of students on environmental change material in MTs 2 Sleman, Sleman Regency Yogyakarta, Indonesia.

METHOD

This study used a pre-experimental method, namely one group of students' study with a one-group pretest-posttest design. Students in the group have conducted a learning process in a scientific approach with DMR learning model. This study was conducted at MTs 2 Sleman from February to September 2020 with participants selected using a simple random sampling technique. Simple random sampling is a sampling technique in

which a sample of size *n* is taken from a population of size *N*, in such a way that every possible sample has the same probability of being selected as a sample. How to take a sample with the simple random sampling technique by numbering all elements in the population, then taking *n* random numbers among *N* numbers, and finally the elements with selected numbers as sample members (Creswel, 2013). There were 60 students (41 females and 29 male) selected from class 8th (second grade in junior high school) as the subject of this study who follow the natural sciences courses, especially in environment change subject material and based on the criteria of the same academic ability in science learning (homogenous). All of the students as participants have agreed to participate in this study. The study was conducted in accordance with the Declaration of Helsinki (Ashcroft, 2008).

The CTS test consisted of 14 items, two questions for each indicator have given in pre-test and post-test (see APPENDIX I). For each test question, a statistical test calculation used Winstep version 3.73 to analyze how the person-reliability (subject) and items-reliability (question), and how to measure the order of items referred to the Rasch Model analysis, a fit item model for one-parameter logistic. Each question is rated based on the formula in Table 1 that is an average score and standard deviation. Then, the score was classified into some groups by comparing yields between the average scores and standard deviations (Permatasari et al., 2019), as shown in Table 1.

Table 1
Interpretation of Students level of CTS

Score	Category
X > Average + Standard Deviation	High
Average – Standard Deviation < X ≤ Average + Standard Deviation	Medium
X ≤ Average – Standard Deviation	Low

The enhancing students CTS calculated using N-Gain formulas from Hake (Hake, 1998), as shown in Table 2.

Table 2
Interpretation N-Gain <*g*>

<*g*>	Category
$g > 0.7$	High
$0.3 < g \leq 0.7$	Medium
$g \leq 0.3$	Low

Finally, a parametric statistic paired sample t-test was used to test the research hypothesis. The hypothesis in this study is initial hypothesis "H_0: DMR learning model on environmental change topics does not affect student critical thinking skills" and the alternative hypothesis "H_a: DMR learning model on environmental change topics does affect student critical thinking skills". These tests analyze the effectiveness of DMR learning model to improve CTS. Besides, students' scores were also analyzed by gender to obtain information about how gender affects CTS by using DMR learning model process.

FINDINGS AND DISCUSSION

Rasch Model Analysis

Students' score of CTS was measured by giving 14 questions, two questions represent each indicator, showed that students have a low level of CTS. Rasch Model analysis done included person-reliability, item-reliability, and a fit item measure. Person reliability or score that show how consistent student to answer correctly is 0.82 with separation 2.14. This score indicates that students may answer a question correctly in a "good" category (Boone et al., 2011). That means the students answer following the pattern where students consistently answered right, or wrong for a difficult question. Separation scores, or scores that show how good subjects separate items, 2.14 indicated that students' scores of CTS have good enough distribution (Boone & Noltemeyer, 2017). For item separation, items in these tests could be classified students, based on their answer, into 3 groups that are high levels, middle level, and low-level competencies.

Table 3
Summary statistics on Rasch analysis

Indicator	Value
INFIT MNSQ	1.01
INFIT ZSTD	-0.1
OUTFIT MNSQ	0.99
OUTFIT ZSTD	-0.1
Standard Deviation	0.85
Person Raw Score-to-Measure Correlation	0.82
Separation	2.14
CRONBACH ALPHA (KR-20)	0.81

Table 3 shows that the person measures with the number 0.00 indicated that the average student's ability is at the same level as the question (set by default 0.00). The OUTFIT-MNSQ score shows the number 0.99 which means that the questions are accepted, or excellent in measuring. Furthermore, the OUTFIT-ZSTD score of -.1 has a high level of reliability. According to interpretation by (Boone et al., 2013; Linacre, 2012), the values for OUTFIT-MNSQ is from 0.5 to 1.5 and the values for the OUTFIT-ZSTD are from -2 to +2. Next is the Cronbach alpha value, this value shows how the students' internal consistency is in answering questions. Therefore, this score is not fully part of the statistical analysis, but to show the reliability between the students (who answered) and the questions (who were asked). In this study the reliability of the instrument seen from the Cronbach alpha value is 0.81 which means "acceptable" (Gliem & Gliem, 2003). Further analysis is based on Wright-Map, as shown in Figure 1.

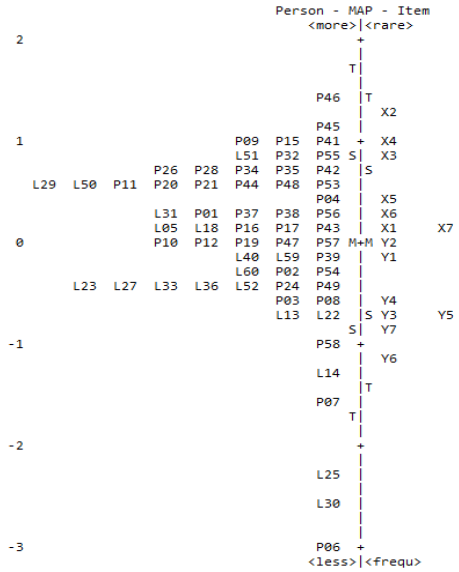

Figure 1
Wright Map (Left: Person ability; Right: Items Difficulties)

Student CTS

The students' CTS is shown by enhancing through the pre-test, post-test, and N-gain scores shown in Table 4.

Table 4
Score pre-test, post-test, and N-Gain in CTS

CTS Aspects	Score		<g>	Category
	Pre-test	Post-test		
Clarity assumption	45.00	50.83	0.11	Low
Interpretation	28.33	8.75	0.28	Low
Analysis	33.75	60.00	0.40	Medium
Inference	32.50	58.33	0.38	Medium
Evaluation	40.00	62.08	0.37	Medium
Reason	42.08	67.50	0.44	Medium
Self-regulation	46.67	63.75	0.32	Medium
Average	38.33	58.75	0.35	Medium

Based on Table 3, the N-Gain of each indicator is at low to medium levels. In general, the increase in CTS has an average value of 0.35 with medium interpretation. The details of the number of students in each category of increasing CTS are presented in Table 4.

Table 4
Number of Students in Each Category N-Gain

Number of students	Percentage (%)	Category
1	1.67	High
35	58.33	Medium
24	40.00	Low

However, students can also be grouped into three high, medium, and low CTS abilities based on their achievement, mean, and standard deviation, shown in Table 5.

Table 5
Student's CTS Level

Level of CTS	Number of Students		Percentage (%)	
	Pre-Test	Post-Test	Pre-Test	Post-Test
High	10	7	16.67	11.67
Medium	42	44	70.00	73.33
Low	8	9	13.33	15.00

Based on Table 5, there is a decrease in the number of students and the percentage in the High category and there is an increase in the medium and low categories. These results are in the fair category where the mean and St. Deviation at post-test 58.75 and 17.27 was greater than at pre-test, namely 38.33 and 10.66. Furthermore, grouping students by gender also shows that female students have a greater increase compared to male students, as seen in Figure 3.

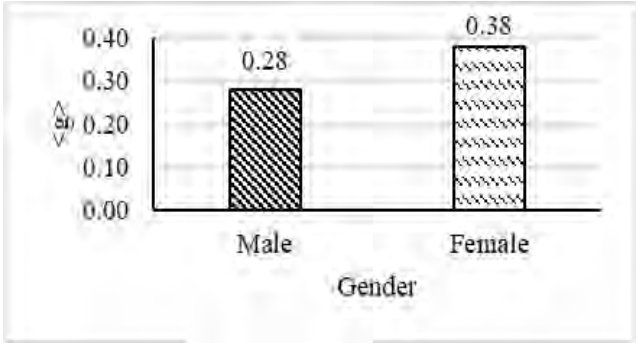

Figure 3
Normalized gain Score on Gender

The effectiveness of the DMR learning model in improving students CTS

The effectiveness of learning is measured by hypothesis testing which also aims to identify the effect of the treatments given on improving CTS. However, before testing the hypothesis, it is necessary to test the prerequisite analysis first, namely data normality. The results of the data normality test are shown in Table 6.

Table 6
Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Pre	.114	60	0.051
Post	.106	60	0.090

Based on Table 6, the results of the pre-requisite test, normality test, show that the distribution of scores in both the pre-test and post-test questions is normal. This refers to a significant value greater than 0.05 so that a statistical test can be done, namely the paired sample t-test as the results is shown in Tables 7, 8, and 9.

Table 7
Paired Samples Statistics

		Mean	Number of Students	Standard Deviation	Standard Error Mean
Pair 1	Pre	38.33	60	10.66	1.38
	Post	58.75	60	17.26	2.23

Table 8
Paired Samples Correlation

N	Correlation	Sig.
60	.792	.000

Table 9
Paired Samples Test

Paired Differences			t	Sig. (2-tailed)
Mean	Standard Deviation	Standard Error Mean		
-20.42	10.96	1.42	-14.43	.00

Table 7 indicated that the overall average score of students during the post-test is greater than during the pre-test. The standard deviation and error values at the time of the post-test were also greater than those of the pre-test, so it can be concluded that the distribution of data or range of values during the post-test is more varied than during the pre-test which causes the greater the possibility of calculation errors using post-test data. However, this score is still at a good acceptance level where the pre-test only has an error value of 1.38 and the post-test of 2.23.

In Table 8, there is a sample correlation value of 0.792 and a significance of 0.00. The correlation value of 0.792 > 0.05 indicates that there is no relationship between pre-test and post-test scores. Besides, this value can also be expressed as a Pearson Correlation with the interpretation that 0.792 > 0.5 that the two values have a strong correlation.

Furthermore, in Table 9, the mean value of -20.42 is the difference between the initial and final means where the negative sign (-) indicates that the post-test score is greater than the pre-test value. Furthermore, from the difference score, there is a fairly large distribution of pre-test and post-test values as indicated by the standard deviation value

of 10.96 and the calculation error of 1.42. The value of t (t count) and significance (Sig. 2 tailed) can be used as a basis for conducting hypothesis testing where if t count > t table or if t count <-t table then the treatment has a significant effect on the results. In this study, the value used as the basis for decision-makers was a significance value of 0.00 <0.05, which means that there is a difference in the average pre-test and post-test results, which means that the treatments carried out have a significant effect on increasing student CTS (Chatfield, 2018).

Enhancing students' CTS

The enhancement of students' CTS which is known from Table 3 shows that students' CTS in environmental change material becomes better after learning using the DMR-LM. This is in line with the research of Ningsih, et. al., (2012) which states that the guided discovery-oriented learning model can improve students' CTS.

From seven aspects of CTS, aspect "reasoning" has the highest N-gain value, namely 0.44, including in the medium category. This is because at each meeting students are trained to make explanations in the form of arguments based on experiments and concepts that have been found. This is in line with the research results presented by Gunawan & Lestari (2020) and Simamora et al. (2018) state that with discovery-based learning students become accustomed to analyzing to solve problems based on concepts that have been built from the results of group experimental activities. Besides, learning activities always involve students to rebuild information and knowledge and develop their understanding by looking for additional references to solve a problem (Saputra et al., 2019; Saputri et al., 2019). While the clarity assumption aspect has the lowest N-gain value, namely 0.11, which is included in the low category. This is because students are not maximal in identifying assumptions related to the material. After all, students can be more optimal in building and connecting their knowledge by exchanging opinions in groups to solve complex problems (Häkkinen et al., 2017; Ningsih et al., 2012)

The details of the number of students in each category of increasing CTS are presented in Table 4, it appears that the majority of the increase in student CTS in the medium category is 58.33% and the low category is 40.00% because students and teachers are still constrained in applying the DMR learning model, such as at the orientation stage, most students are less precise in identifying assumptions related to environmental changes. This is related to the lack of thinking skills of students in connecting concepts to one another. It is better if before learning begins the teacher explains a small part of the material which is the prerequisite material, even though this material has been studied in elementary school, but most students usually forget or do not understand the basic material (McIntyre et al., 2018; Unal & Unal, 2017; Basri et al., 2019). This is in harmony with the opinion of Wardono et al. (2020) which states that the orientation stage should begin with the provision of information or data and be guided by questions to be able to draw a temporary conclusion.

Further information that can be analyzed is related to the distribution of students' abilities based on gender classification. According to Figure 2, female students (symbolized by P) are predominantly at the top, while the female is at the bottom. This

means that the students from this study showed that female students had better CTS than male students. The findings of this study are by the findings of Liu et al. (2019) and Fuad et al. (2017)that is, in terms of critical analysis thinking skills, female students score is higher than that of men. They are also esteemed higher than males in making conclusions or decision aspects, which means that female students were better to identify the elements needed to make conclusions, to form hypotheses, and to be concerned about relevant information. Thus, it can be concluded that in female, the brain territories related to language function work harder those results in better language skills. According to Guiller (2005) and Eagly et al. (2020) state that women have more ability to convey their opinions to others. Research conducted by James (2015) found that male adolescents generally perform better on visual and mathematical skills while females perform better on verbal assignments, such as sentence writing, correct spelling, reading, and pronunciation. Downing et al. (2008) also found that men have more especially good in manipulating visual images and numerical, while female generally did better on tests of verbal ability (Toivainen et al., 2017).

Enhancing students' CTS

The effectiveness of the DMR learning model to improve students' CTS can be seen from the results of hypothesis testing. By calculating the hypothesis test using the paired sample t-test, the value is obtained $_{count}$ = 14.43 with a significance level of 0.05 the value t_{-table} = 2.000. Based on these data indicate that the value t_{-count} greater than the value t_{-table} (14.43>2.000), so that the hypothesis initial (H_0) is rejected. Thus, it shows that there is a significant impact on the application of the DMR learning model in improving students' CTS on environmental change material.

Make it easier for students to understand the material because science concepts can be explored through several forms of representation, such as verbal, image, physical representation, and mathematics. The DMR learning model guides students to understand the material by coherently using multiple representations; starting with verbal, pictorial, physical, and ending with mathematics. In line with the findings by Leigh (2004), students will have a better understanding of concepts when starting with descriptive (verbal) understanding, then, continuing with pictures and diagrams, and ending with mathematical equations. Previous studies by Namdar & Shen (2018) states that knowledge can be organized using multiple representations to achieve a comprehensive understanding. Another study conducted by Gilbert & Treagust (2009), students better understand the concept by using several representations compared to using only one particular representation.

Activities in the application of the DMR learning model can also help students find their concepts independently because each student in the group has the opportunity to investigate. The effect of the active discovery process by students is the understanding of concepts that are stored in memory for a long time. This finding is supported by Hosnan (2014), that through discovery learning can have an impact on long-term understanding as a result of the maximum role of learners. Further stated by Pratiwi & Rasmawan (2014) also stated that the scientific method-based learning model can affect the improvement of critical thinking skills.

CONCLUSION

We have successfully studied the implementation of the DMR learning model to improve students' CTS. Through the implementation of the DMR learning model, it has a substantial effect on students' CTS which with the increase is included in the medium category. Therefore, to be able to improve CTS, students are instructed to read and make a synopsis of the topics before applying to the DMR learning model. The teacher should provide clear directions about what activities will be carried out and should remind students about the initial objectives of learning because the goals are closely related to the conclusion. The research may be continued on the subject of science or other subjects at primary or middle schools or even university. Future research can also focus on other thinking skills such as creativity, problem-solving, scientific literation, and others.

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REFERENCES

Abruscato, J. (2003). *Teaching children science: Discovery methods for the elementary and middle grades*. Allyn & Bacon.

Adzim, A. K. (2020). The effectiveness of role-playing methods on student's critical thinking skills in "interaction between creatures and its surroundings" topic in junior high school 1 Berbah. *Journal of Science Education Research*, *4*(2), 76–80. https://doi.org/10.21831/jser.v4i2.35718

Ashcroft, R. E. (2008). The declaration of Helsinki. In E. J. Emanuel, C. C. Grady, R. A. Crouch, R. K. Lie, F. G. Miller, & D. D. Wendler, *The Oxford Textbook of Clinical Research Ethics*, (pp. 141–148). Oxford University Press.

Bano, M., Zowghi, D., Ferrari, A., Spoletini, P., & Donati, B. (2019). Teaching requirements elicitation interviews: an empirical study of learning from mistakes. *Requirements Engineering*, *24*(3), 259-289. https://doi.org/10.1007/s00766-019-00313-0

Basri, H., Purwanto, As'ari, A. R., & Sisworo. (2019). Investigating critical thinking skill of junior high school in solving mathematical problem. *International Journal of Instruction, 12*(3), 745-758. https://doi.org/10.29333/iji.2019.12345a

Boone, W. J., & Noltemeyer, A. (2017). Rasch analysis: A primer for school psychology researchers and practitioners. *Cogent Education*, *4*(1), 1–13. https://doi.org/10.1080/2331186X.2017.1416898

Boone, W. J., Townsend, J. S., & Staver, J. (2011). Using Rasch theory to guide the practice of survey development and survey data analysis in science education and to inform science reform efforts: An exemplar utilizing STEBI self-efficacy data. *Science Education*, *95*(2), 258–280. https://doi.org/10.1002/sce.20413

Boone, W. J., Yale, M. S., & Staver, J. R. (2013). *Rasch analysis in the human sciences*. Springer Science & Business Media. https://doi.org/10.1007/978-94-007-6857-4

Carey, S. S. (2011). A beginner's guide to scientific method. In M. Straton (Ed.), *Learning* (4th ed.). Wadsworth Cengage Learning. https://doi.org/0-495-91356-1

Chang, Y., Li, B.-D., Chen, H.-C., & Chiu, F.-C. (2015). Investigating the synergy of critical thinking and creative thinking in the course of integrated activity in Taiwan. *Educational Psychology*, *35*(3), 341–360. https://doi.org/10.1080/01443410.2014.920079

Chatfield, C. (2018). *Introduction to multivariate analysis*. Routledge. https://doi.org/10.1201/9780203749999

Chiappetta, E. L., & Koballa, T. R. (2010). *Science instruction in the middle and secondary schools: Developing fundamental knowledge and skills* (7th ed.). Pearson Education Inc.

Chusni, M. M., Saputro, S., Suranto, & Rahardjo, S. B. (2020). The conceptual framework of designing a discovery learning modification model to empower students' essential thinking skills. *Journal of Physics: Conference Series*, *1467*, 012015. https://doi.org/10.1088/1742-6596/1467/1/012015

Creswel, J. (2013). *Research design pendekatan kualitatif, kuantitatif, dan mixed*. Pustaka Pelajar.

Dimyati, M. (2006). *Belajar dan pembelajaran*. Rineka Cipta.

Downing, K., Chan, S., Downing, W., Kwong, T., & Lam, T. (2008). Measuring gender differences in cognitive functioning. *Multicultural Education & Technology Journal*, *2*(1), 4–18. https://doi.org/10.1108/17504970810867124

Eagly, A. H., Nater, C., Miller, D. I., Kaufmann, M., & Sczesny, S. (2020). Gender stereotypes have changed: A cross-temporal meta-analysis of U.S. public opinion polls from 1946 to 2018. *American Psychologist*, *75*(3), 301–315. https://doi.org/10.1037/amp0000494

Farisi, M. I. (2016). Developing the 21st-century social studies skills through technology integration. *Turkish Online Journal of Distance Education*, *17*(1), 16–30. https://doi.org/10.17718/tojde.47374

Fuad, N. M., Zubaidah, S., Mahanal, S., & Suarsini, E. (2017). Improving junior high schools' critical thinking skills based on test three different models of learning. *International Journal of Instruction, 10* (1). 101-116. https://10.12973/iji.2017.1017a

Gilbert, J. K., & Treagust, D. (2009). Introduction: Macro, submicro and symbolic representa- tions and the relationship between them: Key models in chemical education. In *Multiple representations in chemical education* (pp. 1–8). Springer. https://doi.org/10.1007/978-1-4020-8872-8_1

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's

alpha reliability coefficient for Likert-type scales. Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education*, 82–88.

Greenstein, L. M. (2012). *Assessing 21st century skills: A guide to evaluating mastery and authentic learning*. Corwin Press.

Guiller, J., Ross, A., & Durndell, A. (2005). The role of gender in a peer-based critical thinking task. In A. Me´ndez-Vilas, B. Gonza´lez-Pereira, J. Mesa Gonza´lez, & J. A. Mesa Gonza´lez (Eds.), *Recent research developments in learning technologies, Vol. I* (pp. 248e252). Formatex.

Gunawan, K., & Lestari, P. A. S. (2020). Instructional materials for discovery learning with cognitive conflict approach to improve vocational students' achievement. *International Journal of Instruction*, *13*(3), 433–444. https://doi.org/10.29333/iji.2020.13330a

Hake, R. R. (1998). Interactive-engagement versus traditional methods : A six-thousand-student survey of mechanics test data for introductory physics courses Interactive-engagement versus traditional methods : A six-thousand-student survey of mechanics test data for introduc. *American Journal of Physics*, *66*(64), 64–74. https://doi.org/10.1119/1.18809

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher-students for twenty-first-century learning practices (PREP 21): A framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching: Theory and Practice*, *23*(1), 25–41. https://doi.org/10.1080/13540602.2016.1203772

Halliru, S., & Slade, B. (2017). Exploring the voice of the young adult in developing lifelong learning attributes: Entrepreneurship and learning-to-learn skills in Nigeria. In G. Kong & E. Boeren (Eds.), *Adult Education for Inclusion and Diversity Conference Proceedings 2017* (pp.170-176). Centre for Research in Education Inclusion & Diversity, University of Edinburgh.

Hosnan, M. (2014). *Pendekatan saintifik dan kontekstual dalam pembelajaran abad 21: Kunci sukses implementasi kurikulum 2013*. Ghalia Indonesia.

Hugerat, M., & Kortam, N. (2014). Improving higher order thinking skills among freshmen by teaching science through inquiry. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(5), 447–454. https://doi.org/10.12973/eurasia.2014.1107a

Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. In In J. M. Spector, J. G. van Merrienboer, M. D., Merrill, & M. Driscoll (Eds.), *Handbook of Research on Educational Communications and Technology* (3 ed., pp. 485-506). Erlbaum. https://doi.org/10.4324/9780203880869.ch38

James, A. N. (2015). *Teaching the male brain: How boys think, feel, and learn in school*. Corwin Press. https://doi.org/10.4135/9781483393407

Ledward, B. C., & Hirata, D. (2011). *An overview of 21st century skills: Summary of 21st century skills for students and teachers*. Pacific Policy Research Center of Kamehameha Schools.

Leigh, G. (2004). *Developing multi-representational problem solving skills in large, mixed-ability physics classes*. University of Cape Town.

Linacre, J. M. (2012). *A user guide to Winsteps Ministep Rasch model computer programs: Program manual 3.75.0.* MESA Press.

Liu, N.-Y., Hsu, W.-Y., Hung, C.-A., Wu, P.-L., & Pai, H.-C. (2019). The effect of gender role orientation on student nurses' caring behaviour and critical thinking. *International Journal of Nursing Studies*, *89*(January), 18–23. https://doi.org/10.1016/j.ijnurstu.2018.09.005

Maknun, J. (2020). Implementation of guided inquiry learning model to improve understanding physics concepts and critical thinking skill of vocational high school students. *International Education Studies*, *13*(6), 117. https://doi.org/10.5539/ies.v13n6p117

McIntyre, T., Wegener, M., & McGrath, D. (2018). Dynamic e-learning modules for student lecture preparation. *Teaching and Learning Inquiry*, *6*(1), 126–145. https://doi.org/10.20343/teachlearninqu.6.1.11

Memon, G. R. (2007). Education in Pakistan: The key issues, problems and the new challenges. *Journal of Management and Social Sciences*, *3*(1), 47–55.

Namdar, B., & Shen, J. (2018). Knowledge organization through multiple representations in a computer-supported collaborative learning environment. *Interactive Learning Environments*, *26*(5), 638–653. https://doi.org/10.1080/10494820.2017.1376337

Nauman, S. (2017). Lack of critical thinking skills leading to research crisis in developing countries: A case of Pakistan. *Learned Publishing*, *30*(3), 233–236. https://doi.org/10.1002/leap.1091

Ningsih, S. M., Bambang, S., & Sopyan, A. (2012). Implementasi model pembelajaran process oriented guided inquiry learning (POGIL) untuk meningkatkan kemampuan berpikir kritis siswa. *UPEJ Unnes Physics Education Journal*, *1*(2), 44–52. https://doi.org/https://doi.org/10.15294/upej.v1i2.1364

OECD (2019). *The Programme for International Student Assesment (PISA) Result from PISA 2018*. OECD Publishing.

OECD (2017). *Results (Volume III): Students' Well-Being*. OECD Publishing.

Permatasari, A. K., Istiyono, E., & Kuswanto, H. (2019). Developing assessment instrument to measure physics problem solving skills for mirror topic. *International Journal of Educational Research Review*, *4*(3), 358–366. https://doi.org/10.24331/ijere.573872

Pratiwi, F. A., & Rasmawan, R. (2014). Pengaruh penggunaan model discovery learning

dengan pendekatan saintifik terhadap keterampilan berpikir kritis siswa SMA. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa*, *3*(7), 1–18.

Roser, M., Nagdy, M., & Ortiz-Ospina, E. (2013). *Quality of Education*. Retrieved from: https://ourworldindata.org/quality-of-education.

Rotherham, A. J., & Willingham, D. T. (2010). "21st-Century Skills" Not New, but a Worthy Challenge. *American Educator*, *17*(1), 17-20.

Rustaman, N., Toharudin, U., Hendrawati, S., & Rustama, A. (2011). *Membangun literasi sains peserta didik*. Humaniora.

Saleh, S. E. (2019). Critical thinking as a 21st century skill: Conceptions, implementation, and challenges in the efl classroom. *European Journal of Foreign Language Teaching*, *4*(1), 1–16. https://doi.org/10.5281/zenodo.2542838

Saputra, M. D., Joyoatmojo, S., Wardani, D. K., & Sangka, K. B. (2019). Developing Critical-Thinking Skills through the Collaboration of Jigsaw Model with Problem-Based Learning Model. *International Journal of Instruction*, *12*(1), 1077–1094. https://doi.org/10.29333/iji.2019.12169a

Saputri, A. C., Sajidan, S., Rinanto, Y., Afandi, A., & Prasetyanti, N. M. (2019). Improving students' critical thinking skills in cell-metabolism learning using stimulating higher order thinking skills model. *International Journal of Instruction*, *12*(1), 327–342. https://doi.org/10.29333/iji.2019.12122a

Silberman, M. (1996). *Active Learning: 101 Strategies To Teach Any Subject.* ERIC.

Simamora, R. E., Saragih, S., & Hasratuddin, H. (2018). Improving Students' Mathematical Problem Solving Ability and Self-Efficacy through Guided Discovery Learning in Local Culture Context. *International Electronic Journal of Mathematics Education*, *14*(1), 61–72. https://doi.org/10.12973/iejme/3966

Toivainen, T., Papageorgiou, K. A., Tosto, M. G., & Kovas, Y. (2017). Sex differences in non-verbal and verbal abilities in childhood and adolescence. *Intelligence*, *64*(September), 81–88. https://doi.org/10.1016/j.intell.2017.07.007

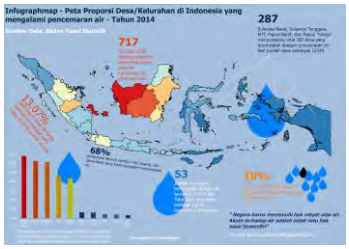
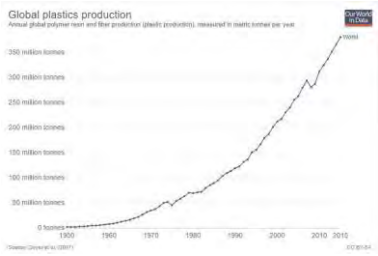
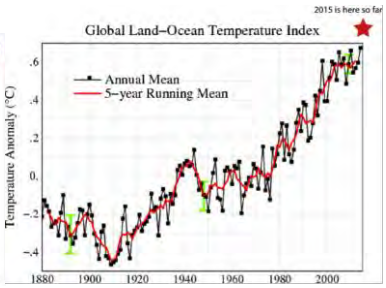
Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. Jossey-Bass.

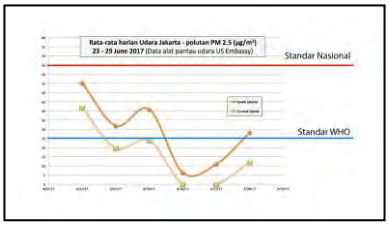
Unal, Z., & Unal, A. (2017). Comparison of student performance, student perception, and teacher satisfaction with traditional versus flipped classroom models. *International Journal of Instruction*, *10*(4), 145–164. https://doi.org/10.12973/iji.2017.1049a

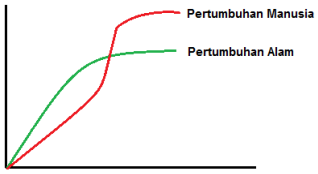
Wardono, R., Uswatun, K., & Mariani, S. (2020). Comparison between generative learning and discovery learning in improving written mathematical communication ability. *International Journal of Instruction*, *13*(3), 729–744. https://doi.org/10.29333/iji.2020.13349a

APPENDIX I

No	Indicator	Pre-test		Post-test	
1	Clarity assumption	Recently we were surprised by an instant noodle plastic waste found at Sendang Biru Beach in the south of Malang Regency, East Java. Ironically, this garbage was found by a student, Fianisa Tiara Pradani, when she was researching Marine Science on the beach. The photo of the trash with the words "Dirgahayu 55 Tahun Indonesiaku" was uploaded through his Twitter social media account and managed to highlight the attention of the Minister of Fisheries and Marine Affairs, Susi Pudjiastuti. Last November 2018, Susi Pudjiastuti will continue to encourage activities to reduce plastic use. This is done to save Indonesia's sea, which is already contaminated with dangerous plastic waste. Minister of Marine Affairs and Fisheries, Susi Pudjiastuti, said that Indonesia is the second-largest contributor of plastic waste in the world which is dumped into the sea. Plastic waste is very dangerous. BPS noted that 10 billion plastic bags are disposed of in the environment per year or as many as 85,000 tons of plastic bags. Recently we were surprised by an instant noodle plastic waste found at Sendang Biru Beach in the south of Malang Regency, East Java. Ironically, this garbage was found by a student, Fianisa Tiara Pradani, when she was researching researching Marine Science on the beach. The photo of the trash with the words "Dirgahayu 55 Tahun Indonesiaku" was uploaded through his Twitter social media account and managed to highlight the attention of the Minister of Fisheries and Marine Affairs, Susi Pudjiastuti. Last November 2018, Susi Pudjiastuti will continue to encourage activities to reduce plastic use. This is done to save Indonesia's sea, which is already contaminated with dangerous plastic waste. Minister of Marine Affairs and Fisheries, Susi Pudjiastuti, said that Indonesia is the second-largest contributor of plastic waste in the world which is dumped into the sea. Plastic waste is very dangerous. BPS noted that 10 billion plastic bags are disposed of in the environment per year or as many as 85,000 tons of plastic bags. If this plastic waste is not collected properly, it will be carried into the rivers and even into the sea and eventually pile up. Because of its light mass, plastic waste will be at sea level so it can cover the sea surface. Waste that is disposed of into the		The current coronavirus pandemic has increased the volume of medical waste. Not only in Indonesia, but in almost all countries in the world. This is a problem in itself because medical waste that is thrown away can have an impact on health. Medical waste that is suspected of being related to the handling of the Covid-19 outbreak such as masks, gloves, and tissues was found scattered in the Sumurbatu landfill (TPA), Bekasi City, and TPA Burangkeng, Bekasi Regency, West Java. How should medical waste be managed during the current coronavirus pandemic? The Urban and Energy Campaign Manager for the Indonesian Forum for the Environment (Walhi) Dwi Sawung said that the abundant medical waste included personal protective equipment (PPE). According to him, handling medical waste is not difficult. Also read: The Bekasi City Government Traces Those Who Dispose of Medical Waste to the Sumur Batu TPA The hospital can sort and disinfect the medical waste. "Sort it first. Can be disinfected in a variety of ways and then chop it so that it is not misused," Dwi said when contacted by Kompas.com, Thursday (2/7/2020). After that, the medical waste can be disposed of in the landfill or recycled. Dwi explained, disinfection can be done by autoclave or spraying disinfectant, or drying it. Hospitals, he continued, have autoclaves that can be used to sterilize reused equipment. Currently, many hospitals (RS) are working with third parties in handling medical waste. "The hospital only collects on-site, later a third party will take it for transport or management," he said. Dwi said most of the hospitals had separated medical waste. However, hospitals in the regions experienced difficulties because no third party was invited to work together to manage these used medical items. Dwi assessed that the government must supervise and improve existing regulations. "Currently only incineration or incineration, even though there are other methods (autoclave). You can use it (autoclave). If you have funds, buy a large autoclave specifically for waste," he explained. Source: https://www.kompas.com/tren/read/2020/07/03/070200865/menyoroti-pembuangan-limbah-medis-pada-masa-pandemi-virus-corona-?page=all.	

	sea can cause environmental damage to marine ecosystems and endanger marine populations. Source: https://www.kompasiana.com/pennylraja/5d3e934a0d82302404292872/laut-indonesia-darurat-sampah-kita-harus-bagaimana Based on the text in the image, explain the problem that must be solved!	Author: Mela Arnani Editor: Inggried Dwi Wedhaswary Based on the text in the image, explain the problem that must be solved!
2 Interpret ation	 Based on the infographic in the image, provide your scientific statement regarding the information and data presented. Include arguments from a scientific point of view.	 Based on the infographic in the image, provide your scientific statement regarding the information and data presented. Include arguments from a scientific point of view.
3 Analysis	Based on the graph in the figure (graph of plastic use from 1950 to 2015), it is known that there has been a significant increase in plastic use. If this state continues to increase, what will happen to nature? given that plastic is quite difficult to be broken down by microorganisms. Explain your opinion !!! 	Based on the graph in the figure (graph of global temperature change from 1880 to 2000), it is known that there has been an increase in global temperature. If this state continues to increase, what will happen to nature? Explain your opinion! 

<table>
<tr>
<td>4</td>
<td>Inferenc e</td>
<td> 

The following graph is a graph comparing air quality in Central Jakarta and South Jakarta. Make the right conclusions based on the graph!</td>
<td> 

The graph in the figure shows a comparison of human and natural growth. Make the right conclusions based on the graph!</td>
</tr>
<tr>
<td>5</td>
<td>Evaluati on</td>
<td>Food and plastic waste can be said to dominate 

the universe of garbage produced by metropolitan cities. Between them, there were complications. This waste must be managed for a more environmentally friendly minimum of waste. Based on the data in the pictures, provide relevant conclusions and represent tables!</td>
<td><table>
<tr><td>Component</td><td>Composition (%)</td></tr>
<tr><td>Organic</td><td>63.56</td></tr>
<tr><td>Paper</td><td>10.42</td></tr>
<tr><td>Metal</td><td>9.76</td></tr>
<tr><td>Glass</td><td>1.7</td></tr>
<tr><td>Textile</td><td>0.95</td></tr>
<tr><td>Plastic</td><td>1.45</td></tr>
<tr><td>others</td><td>12.16</td></tr>
</table>
The composition of the scattered waste varies widely. In the table is the composition of waste in Bandung city in 2008. Make a conclusion that explains the data in the table!</td>
</tr>
<tr>
<td>6</td>
<td>Reason</td>
<td>In recent years, the use of pesticides has increased significantly, especially in plantations. Pesticides are considered quite effective in controlling pests that attack plants. However, excessive use of pesticides can cause an imbalance in the ecosystem. Another impact caused is the carrying of pesticides by the fruit and vegetables that are consumed. As a result, certain symptoms appeared. Responding to this issue, several solutions were offered: 1) returning to organic plant processing, 2) lowering the price of fruits and vegetables that use pesticides, 3) closing pesticide factories. Of the three solutions, provide an analysis of the positive and negative impacts of each solution, and determine the solution that you think is most important to implement.</td>
<td>In everyday life, Indonesian people cannot be separated from plastic. Many benefits are provided by this material. Besides that, plastic is a source of problems because it is difficult to be broken down by microorganisms. Some of the solutions offered to solve the plastic problem are 1) Recycling, 2) Plastic is replaced with paper, 3) closing the plastic factory. Of the three solutions, provide an analysis of the positive and negative impacts of each solution, and determine the solution that you think is most important to implement.</td>
</tr>
</table>

7	Self-regulation	 Based on the problems presented in the figure, what steps/solutions can you take to reduce this impact?	 Based on the problems presented in the figure, what steps/solutions can you take to reduce this impact?